Dispersion by time-varying atmospheric boundary layers

Submitted by

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to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Mathematics, February 2012.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

The periods of time-varying turbulence in the atmospheric boundary layer, i.e. the morning and evening transitions, are often overlooked or highly idealised by dispersion models. These transitions make up a significant portion of the diurnal cycle and are known to affect the spread of pollution due to the properties of turbulence in the residual and stable layers, resulting in phenomena such as lofting, trapping, and fumigation.

Two main simulation techniques are presented for the purpose of modelling the dispersion of passive tracers in both convective and evening transitional boundary layers: Lagrangian stochastic (LS) modelling for 1D, inhomogeneous, non-stationary turbulence; and large-eddy simulation (LES) with a particle model tracing pollutant paths using a combination of the resolved flow velocities and a random displacement model to represent sub-grid scale motions.

In the convective boundary layer, LS models more accurately representing the state of turbulence, and including the effect of skewness, are shown to produce dispersion results in closer agreement with LES. By considering individual particle trajectories, a reflective top boundary in LS models is shown to produce un-physical, sharp changes in velocity and position. By applying a correction to the vertical velocity variance based on representing the stable potential temperature gradient above the boundary layer, particles are contained within the boundary layer in a physically accurate way.

An LS model for predicting dispersion in time-varying, skewed turbulence is developed and tested for various particle releases in transitional boundary layers with different rates of decay, showing an improvement in accuracy compared with previous LS models. Further improvement is made by applying a correction to the vertical velocity variance to represent the effect of a positive potential temperature gradient developing over the course of the transition. Finally, a developing stable boundary layer is shown to have a significant trapping effect on particles released near the surface.

Acknowledgements

First and foremost I would like to thank my supervisors Dr. Bob Beare and Dr. David Thomson for all the help and support they have given me throughout my PhD. I would also like to say thank you to all those at the Met Office and the University of Exeter who offered their input and assistance; I couldn't have done it without you all. My thanks also to the Met Office and the University of Exeter for the funding for this project.

Thank you to my parents for their encouragement, always showing a keen interest in my work and always being there for me; and thanks to all my fellow PhD students and house mates throughout the years, with whom so many good times were had. You guys made Exeter a wonderful place to be!

Most of all I would like to thank my girlfriend, Alice, for her constant support, keeping me motivated when things didn't go to plan, and keeping me calm before my viva, not to mention proof reading my entire thesis! Thank you.

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